# PTTI: UTILIZATIONS AND EXPERIMENTATIONS AT HYDRO-QUÉBEC

Gilles Missout
Hydro-Québec Research Institute (IREQ)
1800 Montée Ste. Julie, Varennes J3X 151, Québec, Canada

**Abstract**

*Hydro-Québec has a long history of PTTI applications. A brief review is presented on our phase angle measurement system and our special modified IRIG-B time code on microwave analog channels which are still in use. This is followed by a description of the use of GPS timing receivers for fault location on high-voltage lines and for synchronous measurement of the power grid. Then our recent experiments of time and frequency transmission on a 250-km overhead fiber optic ground wire is presented. This link uses one in-line optical amplifier. The absolute delay is characterized.*

# 1 INTRODUCTION

Hydro-Québec has extensive experience with PTTI applications. Our first PTTI application consisted of time dissemination system using the Communications Technology Satellite[1], after which we developed a voltage angle measurement system using LORAN-C.[2] The use of power line carriers in the vicinity of LORAN-C signals prevented us from further developing this approach. For this reason and due to parallel developments elsewhere at Hydro-Québec, we built a modified IRIG-B time dissemination[3,4,5] and are searching for other applications.[6] This paper describes the former applications still in use and presents the latest PTTI developments at Hydro-Québec.

# 2 TIME DISSEMINATION ON ANALOG MICROWAVE CHANNELS

## 2.1 IRIG-B

IRIG-B was not successful with its standard configuration for two reasons: 1) the spectrum of the IRIG-B signal is not well adapted to the channel voice bandpass, and 2) the SSB modulation of the microwave link adds phase distortion. Use of a 2-kHz modulated carrier plus a pilot reference at 1 kHz provides a good way to disseminate time with an accuracy of about a few microseconds.

We have a master clock which is based on a triple system using a RbFS driving two time accumulators and a GPS clock. A majority decision system chose one clock to disseminate the timing signal in our network. Slave clocks placed at strategic points acted as protection against loss of the communication channel. Local Units are used in every substation to recover and distribute a standard IRIG-B code to users.

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### 2.2 Chronological Recording of Events

The first requirement was to date every event in the power system to the nearest millisecond. Armed with these dates, someone could then possibly be able to retrace the event's history.

### 2.2 Power Frequency Control

Before the broad use of crystal clocks in every household, the electrical networks were the largest time dissemination systems in the world, which everyone depended on to keep their oven range clocks on time. To balance the load and the generation, we centrally controlled part of the generated power to maintain a 60-Hz clock on time compared to our IRIG-B time system. Figure 1 shows the Allan variance of the Hydro-Québec power system compared with the Eastern US system.

### 2.4 Voltage Angle Measurement System

The measurement of the voltage angle found between strategic points on the power system has the effect of applying a giant stethoscope on an electric grid, which reacts like Jell-O when shaken. Signature analysis provides major clues when searching through chronological reports of events, especially during major events (Fig. 2).

A voltage angle measuring system is still in operation. The IRIG-B system ensures the synchronization of remote units and, with the help of local rubidium clocks, has an accuracy rate of about 10 $\mu$s.

### 2.5 GPS Applications

*Portable Clock*

We are equipped with a GPS-based portable clock used to calibrate the propagation delay of the IRIG-B signals.

*Fault Locator*

We have implemented an approach similar to the one developed by the Bonneville Power Administration, which also uses GPS as a synchronization system.

## 3 NEW DIGITAL COMMUNICATION SYSTEMS

Hydro-Québec is planning to replace its analog communication system with a SONET-type system using fiber-optic-equipped overhead ground wires. This kind of installation is special due to the fact that the fiber optics are exposed to outside elements (e.g. temperature, wind) to a greater extent than are telecommunications systems, which are usually buried. Also, the remote location limits the number of repeaters or line amplifiers which can be used. Typical hops could attain each 120-130 km.

Such a system requires adequate synchronization and the noise affecting the time and frequency propagation on the fiber optics is an important consideration. We were asked by Hydro-Québec's Telecommunications department to characterize the absolute propagation delay and its noise.

### 3.1 Measurement Setup

The optical link, which is 260 km long, is equipped with an optical line amplifier located about midway down the link. Figure 3 presents a diagram of the measurement setup. Cesium-beam clocks are used over the medium term and GPS clocks for the long term at each end. The 10-MHz output of the Chamouchouanne clock is modulated with a 1-pps marker and then used to externally modulate a laser (Fig. 4).

Halfway down, an optical line amplifier is used to boost the optical signal. At the receiving end, the optical signal is converted into an electrical signal. The 1-pps marker is retrieved to give the absolute delay, and the 10-MHz signal is analyzed in the frequency and time domains using the dual mixer time difference system with a 100-Hz beat frequency.

### 3.2 Measurement Results

Figure 5 shows the drift of the cesium at both points (note the three cesium clocks used at Chamouchouanne). Figure 6 gives the absolute delay over the course of 3 days. Figure 7 gives the TDEV of the received signal. The long-term portion is measured using the 1-pps information, the short-term portion using the 100-Hz beat. Figure 8 gives the frequency domain phase noise. On both curves we see a 0.5 to 1 Hz bump. Figure 9 clearly shows oscillation, related to span swings. The diurnal-nocturnal is included in TDEV.

## 4 CONCLUSION

Hydro-Québec is still active in PTTI applications. Our last measurements revealed a promising future for time and frequency dissemination on fiber-optic-equipped overhead ground wire. A hot topic will be at the convergence of synchronous measurement on power network and information technology.


## 5 ACKNOWLEDGMENTS

The author is grateful to many colleagues, specially to Carlos Cerda-Seitz and Yves Delisles, both from Hydro-Québec's Telecommunication department, which gave us the opportunity and ideas to conduct our fiber-optic experiments. Thanks also go to J. M. Houle, Gilles Provençal, Daniel Gagnon, and Louis Lamarche, whose work was crucial to the good results obtained.


## 6 REFERENCES


[1] G. Missout, and P. Girard 1975, *"Study of a method of clock synchronization by satellite for future Hydro Quebec needs,"* Proceedings of the IEEE Conference, 1975, Toronto, Canada, paper 75204, session 20.

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[6] G. Missout 1987, *" PTTI applications in power utilities,"* Proceedings of the 18th Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting, 2-4 December 1986, Washington D.C., USA, pp. 491-502.

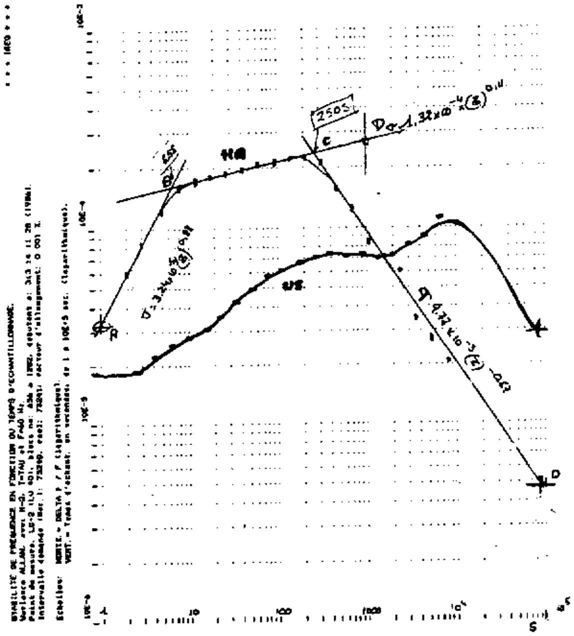


Figure 1. AVAR of HQ and Eastern US power Network

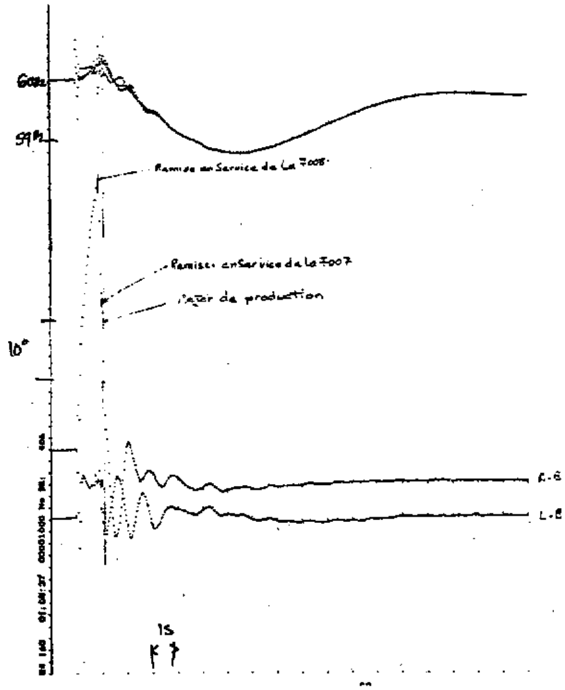


Figure 2. Double short - loss of generation

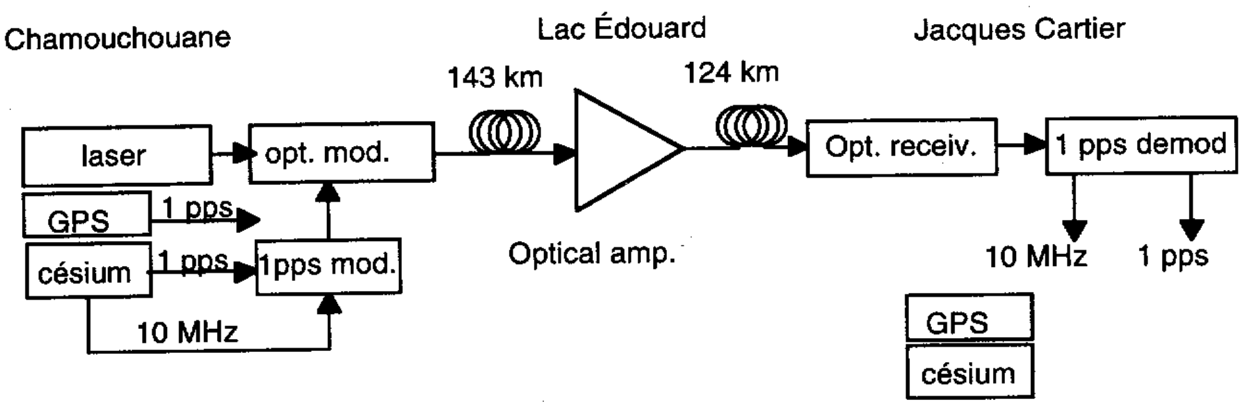



Figure 3. Measurement setup

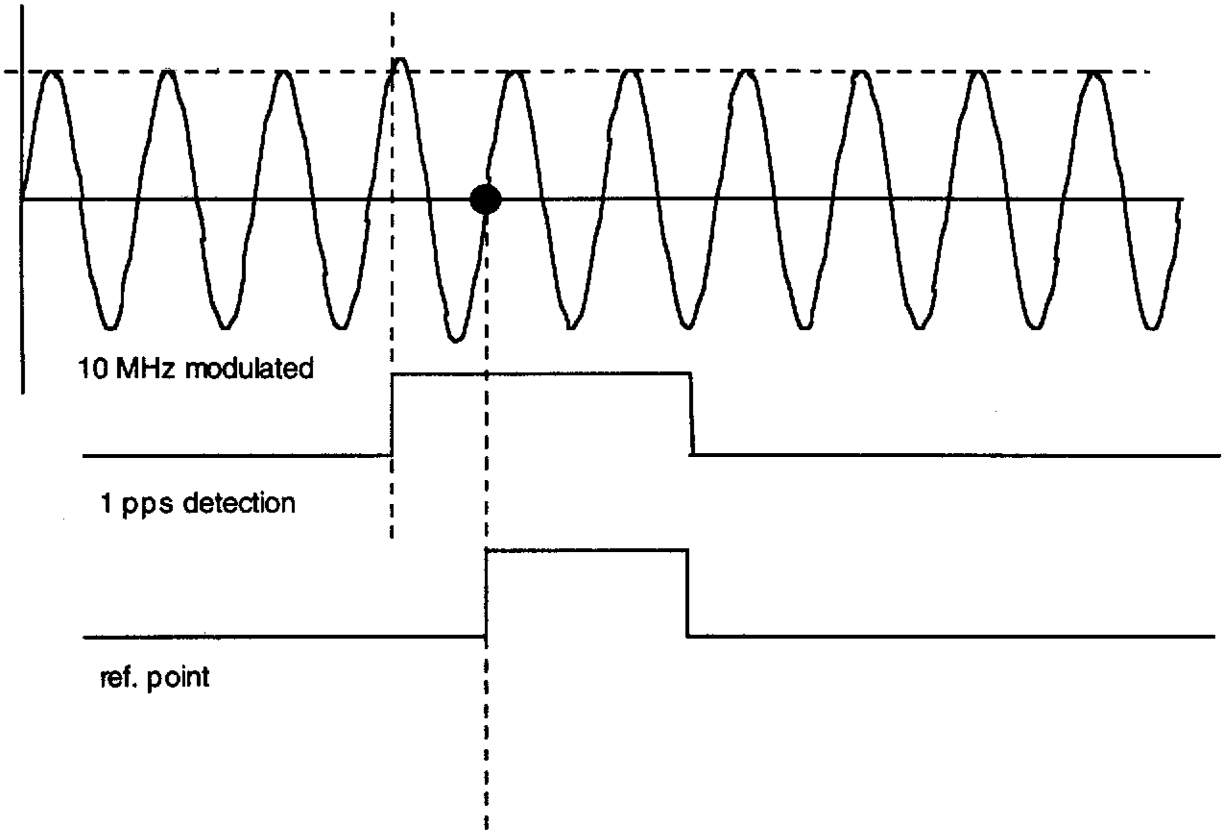



**Figure 4. 1-pps frame information**

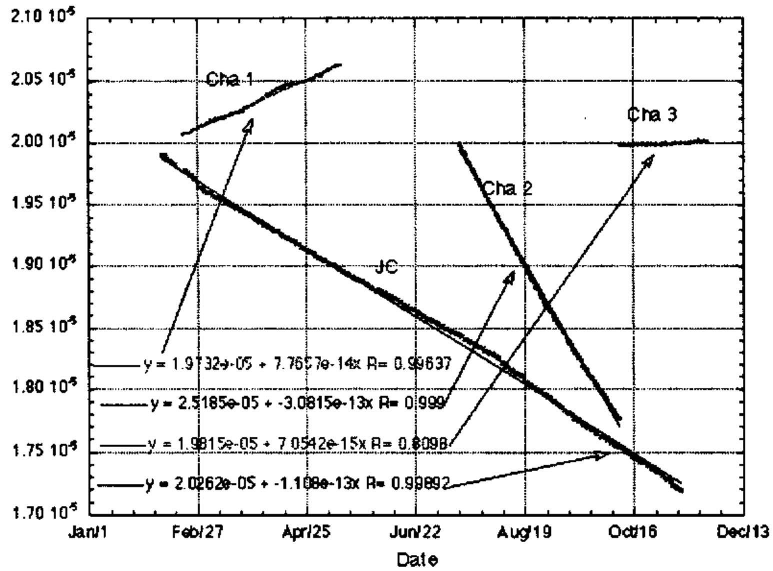



**Figure 5. Cesium drift at both places**

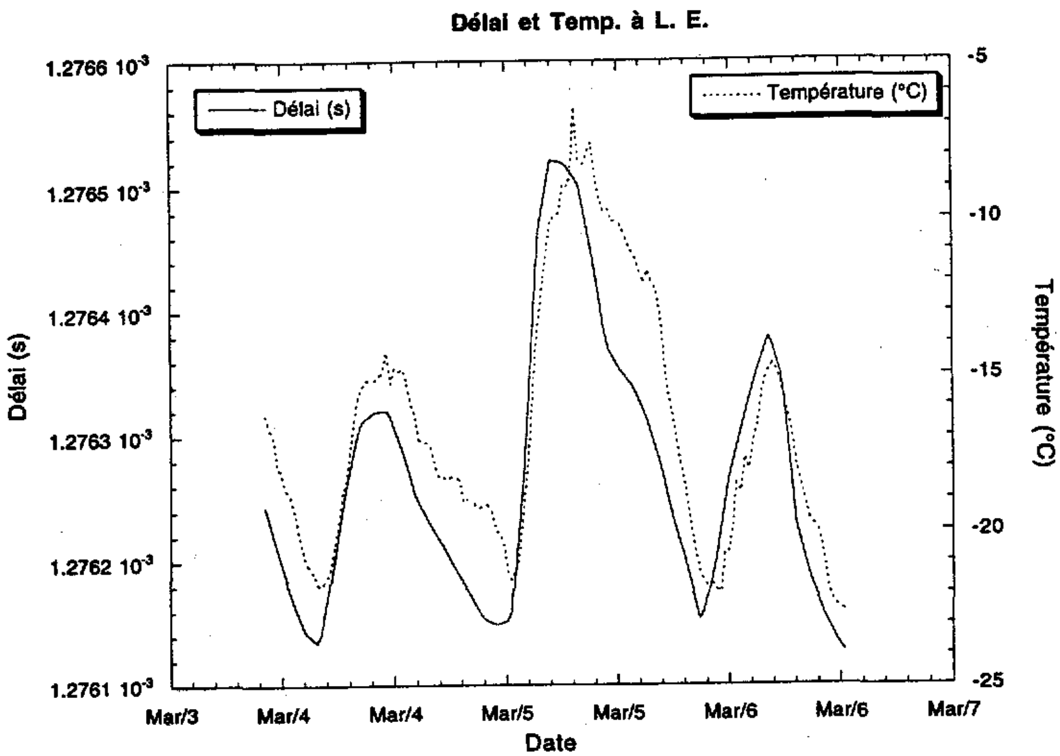



Figure 6. Delay and temperature on 3 days

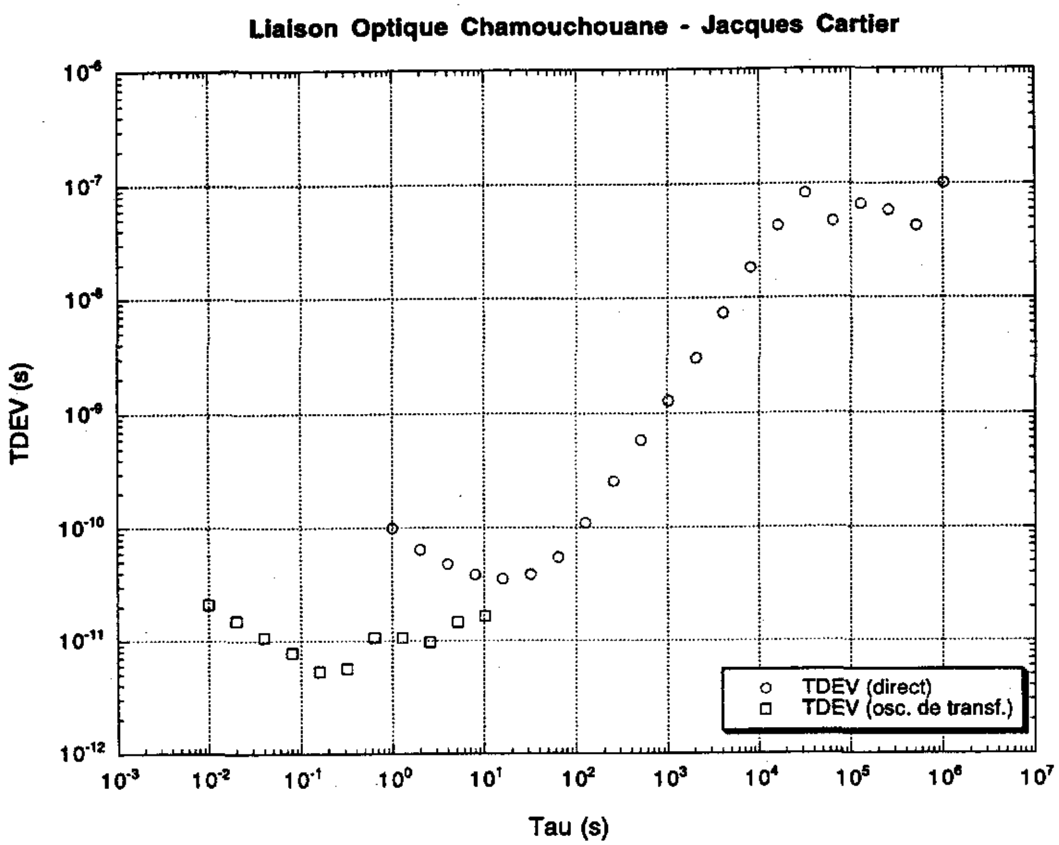
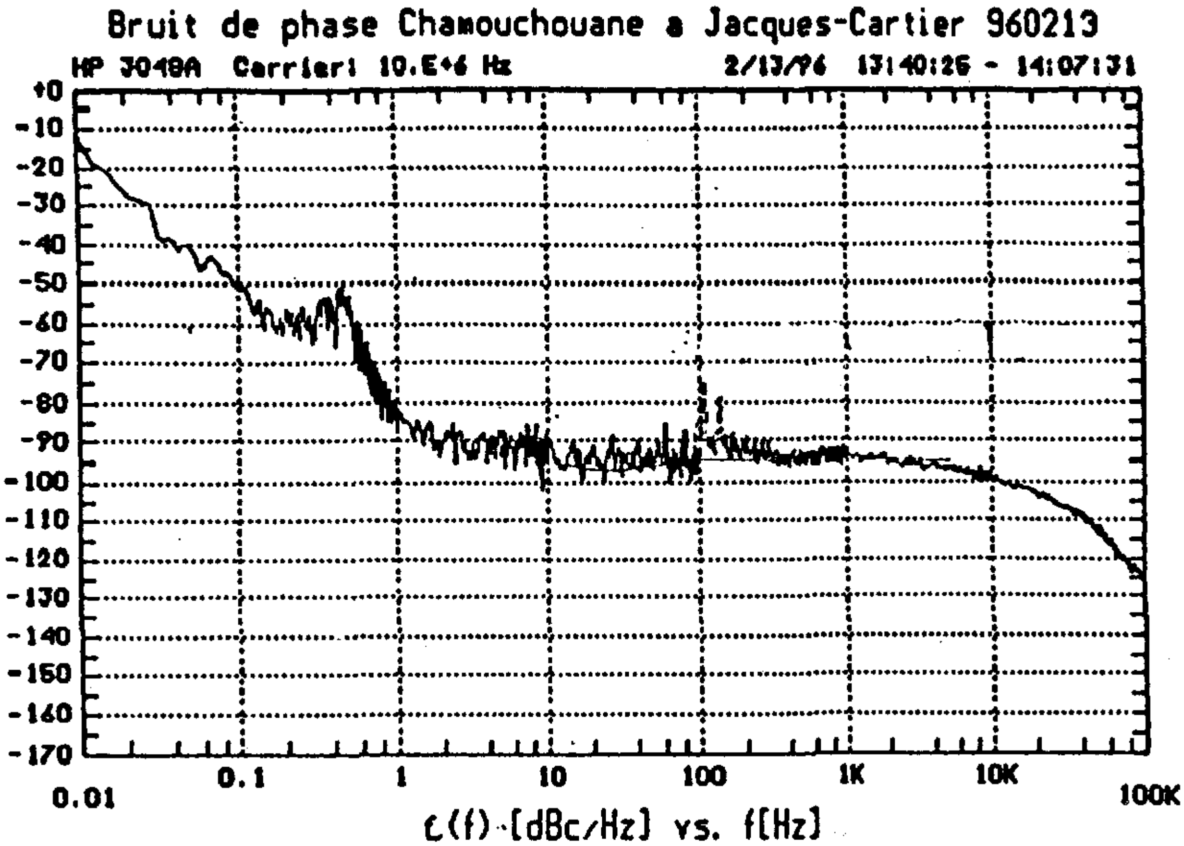



Figure 7. TDEV




Measurement Parameter Summary

| | | | |
|---|---|---|---|
| Meas. Type | PHASE LOCK LOOP | K_VCO Method | MEASURED |
| Start Freq | 10.E-3 Hz | | |
| Stop Freq | 100.E+3 Hz | K_vco | 12.58 Hz/Volt |
| Min. Aves | 4 | Loop Suppr. | VERIFIED |
| Carrier Freq | 10.E+6 Hz | Closd PLL BW | 58.98 Hz |
| Det. In Freq | 10.E+6 Hz | Pk Tune Rnge | 104.900000 Hz |
| Entered Kvco | 10 Hz/Volt | Assumed Pole | 1.727E+3 Hz |
| Center Voltg | 0 Volts | UUT | USER'S SRCE, MAN |
| Tune Range | 10 Volts | Ref. Srce | 10 MHz 'A', SYS, VCO |
| Ph. Detector | 5 TO 1600 MHz | Ext. Tmbase | NOT IN USE |
| K_phi Method | MEASURED | Dn Converter | NOT IN USE |
| K_phi | 468.7E-3 V/Rad | HP11848A LNA | IN |

Figure 8. Phase noise - frequency domain

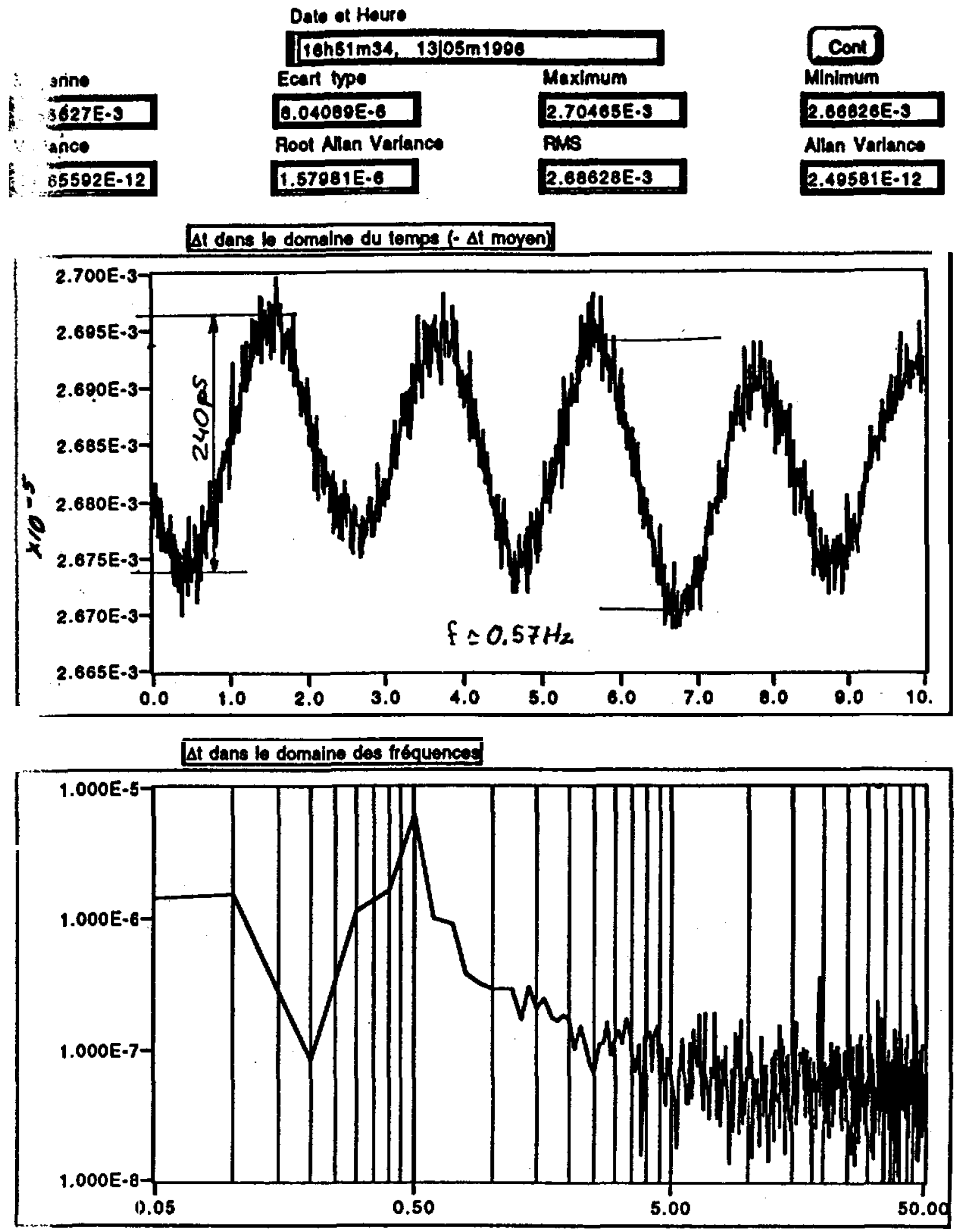



Figure 9. Phase oscillation

## Questions and Answers

RICHARD KEATING (USNO): I understood you to say that the one-half hertz was linked to the slow oscillation of the microwave towers. Is that correct?

GILLES MISSOUT: No. The optical cable is suspended between power utility towers, not microwave towers. So you have towers at, I think, every 300 meters so the cable is suspended there and should calculate the period of oscillation; it's close to .5 hertz.

RICHARD KEATING: Is it driven by wind?

GILLES MISSOUT: Yes.